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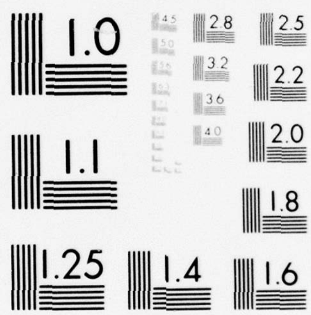

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STUDIES IN SYSTEMATIC INSTRUCTION
AND TRAINING

(12)

THE ROLE OF VERBAL PRESCRIPTIVE RULES
IN COGNITIVE PRETRAINING FOR A FLYING TASK

Fritz H. Brecke
Vernon S. Gerlach
Richard F. Schmid

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Rule Learning and Systematic Instruction in Undergraduate Pilot Training

Vernon S. Gerlach, Principal Investigator

THE ROLE OF VERBAL PRESCRIPTIVE RULES IN COGNITIVE PRETRAINING FOR A FLYING TASK

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I. Verbal Rules in Skill Acquisition

The acquisition of perceptual-motor skills is substantially facilitated when training includes a verbal instruction component (Fitts and Posner, 1967). Brecke, Gerlach, and Shipley (1974) found that when a subject is pretrained with verbal rules, criterion performance of the task occurs more rapidly and with fewer and/or smaller errors. Verbal rules employed as instructional devices can range in form from abbreviated commands to elaborate step-by-step prescriptions on exactly how the skill must be executed (Eubanks, 1976). Since it may be assumed that the various forms have differential effects on skill acquisition, empirical evidence is required to demonstrate which type is most appropriate for a given task. In the following paper, discussion begins with the general role of verbal cognitive rules in the acquisition of perceptual motor skills. It then turns to the more specific area of flight instruction and to rule variations in the acquisition of one specific flight maneuver. The experiment reported here attempts (a) to identify variables, singly and in combination, which increase the effectiveness and efficiency of cognitive pretraining in the form of verbal rules, and (b) to identify and systematically validate principles for the design of verbal rule stimuli used in the initial phase of flight instruction.

Prior work in cognitive pretraining (Brecke and Gerlach, 1972) has led to the formulation of a theoretical framework which allowed the specification of desirable and undesirable characteristics of cognitive pretraining in terms of verbal prescriptive rules. The work of Shannon and Weaver (1949) and of Weltner (1969) in information theory provides the theoretical foundation for the hypothesis that verbal prescriptive rules (VPR) supplied before engaging in a perceptual-motor task reduce the information of the task environment and thus facilitate correct performance. For example, a VPR may specify which one of an array of n possible responses is to be made upon presentation of a certain stimulus. For the naive subject, i.e., the subject who is not supplied with the VPR, all n responses have the same probability of being correct. For the subject who is supplied with the VPR, n-1 of the n possible responses (ideally) have zero probability of being correct and one response has the probability of one (unity). If the VPR is imperfect or if it is imperfectly learned, the reduction of uncertainty or information may not reach this maximum but will assume values somewhere between maximal uncertainty (equal probability of n responses) and maximal certainty (probability of 1.0 for one response). The same argument can be made for any task situation involving choice, e.g., for choosing the proper stimulus to respond to or for choosing the proper goal value to strive for.

Noble, Alcock, and Frye (1959) arrived at a similar explanation using a theoretical framework based on associationistic concepts. Specific instructions, according to their interpretation, elicit fewer competing responses. Since the human operator is assumed to possess a limited information processing capacity, facilitation of perceptual motor learning is more likely when VPRs eliciting fewer competing responses are the basis for cognitive pretraining.

In an empirical investigation of the effect of VPRs by Brecke et al. (1974), eight oral briefings on a specific instrument maneuver (Vertical S-A) as well as the appropriate passages from two manuals (AFM 51-37, ATCM 51-4) were analyzed by four independent judges. It was found that the materials consisted almost solely of VPRs specifying what the pilot should do and when he should do it. These rules were essentially what Miller, Galanter, and Pribram (1970) have called the "learner's crutch" (p. 224) and what Gerlach, Baker, Schultz, and Sullivan (1967) have more rigorously defined as "instructional cues." The instructional cue in the Brecke et al. study was defined as the information (verbal or nonverbal) needed by a learner in order to emit or acquire a specific behavior. The effectiveness of current instructional materials used in undergraduate pilot training (UPT), therefore, could be attributed to the presence of instructional cues in the materials.

The instructional cue as a subset of the concept VPR represents a useful defining characteristic of instruction in general and of cognitive pretraining in particular. The concept can be employed to describe current instructional and experimental materials and permits the specification of a class of stimuli which should be incorporated in cognitive pretraining materials.

Having identified instructional cue as an essential attribute in any cognitive pretraining program, Brecke et al. (1974) developed new instructional cues and compared them to the instructional program employed by UPT.

The use of a control system theory developed by Frank (1969) provided an approach whereby desirable characteristics of instructional cues could be identified and defined. From Frank's work, Brecke and Gerlach (1972) constructed a model of the interactive system pilot-aircraft. The pilot must process three classes of information: (a) information describing desired airplane performance, (b) information describing the control activations which determine airplane performance, and (c) information describing current system performance. These three classes or categories constitute an organizational framework within which it is possible to compile all the relevant information for a given maneuver. The procedure is a task analytic one which has been referred to as a maneuver analysis (Brecke and Gerlach, 1972). Application of a maneuver analysis yields a complete information base specifying the three classes of information for each segment of the maneuver. This information represents the content with which instructional cues for the analyzed maneuver must deal; ideally, it contains neither gaps nor irrelevancies (Gerlach, Brecke, Reiser, and Shipley, 1972).

The control systems model also served as the conceptual background for the development of a list of criteria which permit a purely logical classification of cues into two nominal categories, functional and nonfunctional (Brecke et al., 1974). For example, an instructional cue which specifies an unreliable source of feedback information is nonfunctional as compared to an instructional cue which specifies a reliable source of feedback information for the same behavioral objective. A very primitive operational example may illustrate this point. The pilot's objective may be the achievement and maintenance of a certain vertical velocity. An instructional cue which specifies the vertical velocity indicator as the primary source of feedback information is nonfunctional (this type of instrument lags too much) whereas an instructional cue specifying the attitude indicator as primary source of feedback information is functional. It was assumed that a team consisting of subject matter expert(s) and instructional designer(s) could use these instruments (a maneuver analysis and a list of criteria) to accomplish two tasks: (a) systematic development of instructional cues which satisfy all criteria of functionality, and (b) classification of existing cues as either functional or nonfunctional.

The assumption was tested in the context of instruction for the instrument maneuver Vertical S-A. One instructional designer, who also was a subject matter expert, and three instructional designers who were naive concerning the subject matter created two sets of instructional cues which were highly similar (Gerlach, Brecke, Reiser, and Shipley, 1972). These systematically developed cues were judged to be logically superior to cues identified in current materials. The latter were classified as either functional or nonfunctional by a team consisting of the subject matter expert and one instructional designer who was not familiar with the subject matter. The classification presented very few problems; all of these were solved by reference to the maneuver analysis. All eight briefings exhibited a remarkably stable proportion of functional ($\overline{X}$ = 22.3%) to nonfunctional ($\overline{X}$ = 77.7%) cues. The contrast between systematically developed cues and cues *identified* in current materials is demonstrated in the two lists below. Each list supplies instructional cues for precisely the same flight objective.

List 1 Systematically developed cues	List 2 Cues in current materials
1. Establish 160 and trim	1. Hold 160
2. Note power setting: 82 ± 1%	2. Align J-2 compass
3. Level altitude indicator	3. Check VVI
4. Heading on top of J-2	4. Level altitude indicator

As demonstrated above, it is indeed possible to systematically design instructional cues for perceptual-motor training. Cues so designed will satisfy a set of criteria established on a precise theoretical background.

These cues can be contrasted with cues found in current materials on the basis of the same criteria. The differential effectiveness of currently operational cues and systematically developed cues was tested by comparing the perceptual motor performances of three groups of subjects, each of which had received one of three levels of cognitive pretraining incorporating either currently operational cues or systematically developed cues or no cues (Brecke et al., 1974). The results of this experiment clearly established instructional cue as a powerful form of a VPR and as a highly manipulable variable. Specifically, groups which had received systematically developed cues during pretraining performed significantly better ($p < .05$) than the group receiving no cues on two out of three of the composite performance descriptors employed. The performance difference between the groups receiving currently operational cues and the group receiving no cues was not significant on any of the three descriptors. Neither was there any significant difference between the systematic cue group and the current cue group in terms of composite performance indexes. Comparisons on specific aspects of the maneuver, however, revealed superior performance of the systematic cue group. Error variance on the altitude measure was significantly smaller ($\underline{p} < .05$) for the systematic cue group. This group was also the only group which approached ideal computed elapsed time (129 seconds); the other two groups showed significantly lower ($\underline{p} < .05$) elapsed times.

Thus, even though these results established instructional cues as a researchable variable, they provided no definite support for the hypothesis that systematic cues are instructionally superior to current cues. One possible explanation for this negative result is the lack of practice in the pretraining treatments. In an attempt to make the experimental treatments as similar as possible to currently administered instructional "treatments," overt cognitive practice was omitted from all instruction. All subjects merely read a text (i.e., a manual) "until completely understood" and then received a briefing which was administered by a video monitor. This procedure resulted in very short treatments ($\bar{X}$ = 5.5 minutes), completely devoid of practice and feedback.

Possibly the subjects in the two groups which received cues were not given a sufficient opportunity to learn these cues during cognitive pretraining. If cognitive pretraining is indeed functional, the content must be learned to such a degree of mastery that it can be readily recalled during perceptual motor skill acquisition. An instructional cue functions as a mediator of behavior only if the learner can recall it at the proper moment while he is flying. If higher cognitive mastery and increased availability of the instructional cues are concomitant, then the inclusion of overt practice in the cognitive pretraining phase is indicated. This assumption is based on well established principles of verbal learning and on the results of directly relevant studies, such as those by Baker and Wylie (1950), Holton and Goss (1956), and Goss and Greenfeld (1958), all of whom found that increased levels of practice during cognitive pretraining resulted in increased transfer to perceptual-motor learning.

Mental practice research has also shown that greater performance improvements are likely to result from combinations of cognitive practice and physical practice than from either condition alone. Trussell (cited in Richardson, 1967) found that six days of mental practice (five minutes each day) followed by 14 days of physical practice resulted in the highest gain scores. The second best treatment was physical practice alone; 14 days of mental practice (five minutes daily) followed by six days of physical practice ranked third and mental practice only ranked fourth.

Whether these findings can be generalized to flying training is debatable. It is very difficult to maintain experimental control of the mental practice condition, and such variables as the nature and complexity of the task, the effect of experimental instructions, the amount of time for each condition, and the sequencing of practice have generally been confounded. Moreover, the tasks which have been employed in mental practice research were either ballistic open-loop tasks (for example, basketball throwing) and, therefore, fundamentally different from the closed-loop flying task, or they were closed-loop tasks (for example, rotary pursuit tracking) which were considerably less complex than any flying task.

Despite these limitations, systematically developed cues and currently developed cues were both expected to have little or no facilitative effect on perceptual-motor skill acquisition if subjects had only a minimal amount of prior overt cognitive practice. With a high level of practice, however, systematically developed cues were expected to be highly facilitative, whereas current operational cues were expected to yield little or no facilitative effect.

II. Method

Subjects and Design

Subjects for the experiment had the ability to fly a T-4G simulator in a straight-and-level course; they had no prior instruction in flying the Vertical S-A maneuver. Two flights from the USAF training installation at Williams AFB with a total of 72 student pilots fulfilled these requirements and, therefore, represented the available population. Forty-five subjects were selected from the population by choosing those students with the least extraneous flight experience prior to Air Force training. The sample was diminished by a total of six subjects before and during the experiment.

Three subject characteristics were assumed to be related to performance in the simulator: (a) number of hours in the simulator, (b) number of hours in the airplane, and (c) number of hours of training prior to UPT. The potential impact of differences in these characteristics was difficult to estimate since these variables are confounded with others, such as the type and recency of prior training. If any of the subject characteristics could be shown to correlate with any dependent variable at $r \leq .6$, pre-existing group differences could be taken into account by analysis of covariance procedures (Myers, 1966).

A 2 X 2 factorial design with an independent control group and measures of two dependent variables was employed. The first was a cognitive paper and pencil posttest. The second measure was obtained by observing subjects' performances during the training period. The design was a 2 Cues (current vs. systematic) X 2 Practice (low vs. high mastery) mixed analysis of variance.

Apparatus

A flight simulator (A/F37A/T4-G Singer-Link) for the Cessna T-37A was used for the performance of the perceptual-motor task.

An Incre-Logger Model 4409 Data Recorder using precision cassette tape was connected to the analog computer of the flight simulator, tapping the output voltages for the airspeed indicator, the attitude indicator, the vertical velocity indicator, the heading indicator, the altimeter and the tachometers. The data recorder was set to scan all six channels at a rate of one scan per second.

Treatment Materials

Each of the four experimental groups used a linear self-instructional program on the maneuver Vertical S-A. These programmed texts were developed on the basis of materials used in prior experimentation (Brecke et al., 1974). No programs or other self-instructional materials containing the required levels of the independent variables were available. All programs had the same introductory section on the maneuver, the same division of maneuver segments, and identical mastery items requiring an overt written response. Feedback was provided after

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each response. The four program versions differed from each other by type of instructional cue and by amount of practice. Two program versions contained systematically developed cues and two contained currently operational cues. Program versions with the same level of cues incorporated either a high or a low amount of practice. Each program included a posttest at the end. The posttest was identical for all four versions.

The program for the control group had the same introductory section as the four experimental programs. This section was followed by blank pages on which the students were to write in their own words the steps they would follow in executing the maneuver.

The development of the levels of the two independent variables, Instructional Cues and Practice, is described in the following paragraphs.

Levels of Instructional Cue

Systematically developed cues. This set of cues was developed with the aid of a maneuver analysis (Brecke et al., 1972; Gerlach et al., 1972). This analysis specifies three classes of information for every maneuver segment: Aircraft Parameters, Control Parameters and Information Sources. Instructional cues were generated by applying a quasi-algorithmic procedure to the comprehensive and precise information base generated by the analysis. A set of cues generated by one subject matter expert was highly consistent, in terms of cue content, with a set generated by three instructional design experts. However, the two sets were somewhat less consistent with one another in terms of syntax. The most concisely formulated cues from either set were combined into one list which was then subjected to four revision cycles, during which student as well as instructor pilot judgments generated during actual maneuver performance were analyzed and incorporated.

Currently operational cues. This set of cues was developed from current instructional materials. Briefings on the Vertical S-A maneuver given by eight different instructor pilots were covertly recorded in the normal instructional environment, i.e., on the flight line. Transcriptions of all eight briefings were then distributed to four judges who independently identified the instructional cues contained in the briefings. Even though the judges differed greatly in terms of subject-matter knowledge, interrater reliability was in excess of .80 (Brecke et al., 1974). Two judges, independently of each other, then classified the cues as either functional or nonfunctional. A stratified random sample drawn from the pool of cues thus subdivided constituted the set of current operational cues.

The sets of currently operational cues and systematically developed cues were equivalent with respect to number of cues. The two sets constituted the subject matter for the instructional program.

Levels of Practice

The variable "practice" was operationally defined in terms of two levels: the minimal and the maximal amount of practice which appear to be feasible with the type of instructional treatment (programmed instruction) selected. The minimal amount of practice for the complete set of cues for one maneuver segment was one mastery item, which required the learner to "name in correct order" the cues for the segment to which he had been introduced in the preceding frames. In the maximal or high level practice condition, the learner had to respond to the same first item as the low practice groups but then had to emit the same response two more times, once in conjunction with the cues for the preceding segment and once in conjunction with the cues for the following segment.

Program Development

The programs were developed on the basis of the following objective: "The learner can name in writing the set of cues for the instrument maneuver 'Vertical S-A' in correct order."

Objectives calling for learners to apply the cues to such stimuli as a pictorial or photographic representation of the instrument panel would have required different practice items for different levels of instructional cues. Since the inclusion of nonequivalent practice items might have represented an uncontrolled source of variance, the program objectives were restricted to naming behaviors only.

The programs were printed on 8.5" x 11" (21.5 cm x 27.9 cm) paper, and assembled in a spiral-bound booklet.

The programs underwent four revisions, and each version was tested on pilot subjects. As a result of these revisions, inconsistencies were eliminated, feedback was added after each learner response, and test times were noted.

Procedure

Students were normally scheduled one hour apart. An average time of 80 minutes was required for one student to complete the experiment. Usually two students were present: one in the simulator and one in the study carrel. One experimenter could easily direct the flow of subjects and monitor the data collection. Subjects were randomly assigned to one of the five groups.

For the cognitive pretraining, the experimenter placed the subject in the study carrel and instructed the subject to read the sheet of instructions entitled "For Your Information." The subject was told to mark the time he began work on the program and the time he finished the program. The cognitive posttest was taken immediately upon completion of the program. The subject marked the time when he finished the posttest. Perceptual-motor training took place immediately upon completion of the cognitive posttest. The subject was instructed to take a seat in the simulator (left seat). The simulator was in "FREEZE" condition at 15000 feet, 160 knots, 360° and 81% RPM. After a standard USAF communication check, the subject was told to get comfortable, to adjust the rudder pedals and to use a light touch on the stick due to the stick's extreme sensitivity. The hood was then lowered and locked to reduce environmental interference, and the subject assumed control of the simulator after the experimenter had released the "FREEZE" switch.

The experimenter started the recorder, and the subject then flew straight and level for a period of five minutes. After five minutes, the subject started the first Vertical S-A maneuver. Upon finishing the maneuver, the subject flew straight and level for one minute and then started his second Vertical S. The subject continued to alternate Vertical S maneuvers with straight and level intertrial periods until six maneuvers were completed. The recorder was left on through the completion of the last maneuver. The experimenter kept a subject master sheet and a protocol sheet during this time. The subject master sheet served as the basic form for recording subject characteristics and elapsed times for the various phases of the experiment. The protocol sheet was used to record any deviation from experimental procedure, unusual noises, equipment malfunctions, and the experimenter's subjective impressions concerning student behavior.

After the sixth trial, the simulator was again put into the "FREEZE" condition. The subject left the simulator and answered a brief questionnaire designed to obtain some indication of the retention of instructional cues by the subject as well as to elicit some comment and critique of the pretraining procedures and materials. Upon completion of the questionnaire, the subject was dismissed.

Data Collection and Analysis

Cognitive posttests were scored independently for the percentage of correctly written cues by two judges using an algorithm in conjunction with a key. This procedure ensured a highly objective measure, free of any scorer bias.

The raw data for the computation of the perceptual motor performance descriptors were direct measures of six flight variables: airspeed, heading, altitude, vertical velocity, pitch attitude, and power. These measures were obtained automatically at one second intervals by tapping the analog input to the appropriate instruments. The recorder converted the analog voltages to digital signals and recorded these on precision cassette tape.

The precision with which the values of each variable could be identified and recorded was a function of the range of values which needed to be observed and the fixed recording capacity of eight bits per channel (i.e., variable) and observation. Airspeed, for example, had to be observed at the prescribed value of 160 knots plus and minus a margin wide enough to include even gross student errors. This margin was estimated on the basis of prior experimentation and set at +64 and -24 knots, resulting in a range of 88 knots which had to be observed.

Lost Data

Sporadic malfunctions of the mechanical components of the data collection device as well as occasional excessive noise in the analog signal of the simulator computer resulted in a certain amount of invalid data. These data were identified on the basis of a marker code and deleted from the experimental record with the aid of a computer program. The resulting experimental record, therefore, showed valid data interspersed with gaps varying in size from 1 to maximally 23 observations in length. The total loss of data for the experimental record was 3.75%.

The lost data were judged to be recoverable because all dependent measures were continuous, and the loss intervals were very short. The linear interpolation method was found to be most appropriate (Ludemann, 1974).

The procedure was successful for all measured variables except altitude. The recorded data for altitude had a high proportion of discontinuities or jumps which exceeded the performance limits of the simulator system, and were, therefore, not included in the data analysis.

Performance Descriptors

Measures of performance quality were obtained by comparing actual performance with the ideal or prescribed performance. Ideal performance for the Vertical S maneuver can be described in terms of mathematical functions. It is common practice to use certain criterion limits above and below the ideal values. The quality of a performance can then be described by indicating to what degree the actual performance was within a tolerance band described by the criterion limits.

The criterion limits used for the derivation of performance descriptors in the present experiment were based both on experiences gathered with various criterion limits during prior experimentation and on Fitts (1954), who used the standard deviation of the raw scores as criterion limits. A criterion which is more sensitive to differences between groups was obtained by dividing the standard deviation (over all subjects and trials) for a given variable by the square root of the number of groups. This manipulation yields a criterion which represents the standard error between group means and thus gives maximum discrimination between groups.

On the basis of the criterion limits, three different types of performance descriptors were computed using programming software developed for earlier data (Shipley, Gerlach, and Brecke, 1974). These performance descriptors, while interrelated, each summarize different aspects of pilot performance. Percent Time on Criterion (after Fitts, 1954) is a measure which combines a root mean square measure of performance error with the distribution of this error over time. Hit Rate is a straightforward ratio between number of observations which were within criterion limits and total number of observations. Error Amplitude represents the average size of the error exceeding the criterion limits expressed in units of the criterion limit. In order to obtain one single performance score, the values for each descriptor were also combined as a straight linear sum over all five variables.

III. Results

It was hypothesized that transfer from cognitive pretraining to perceptual-motor performance on a standard instrument flight task would be a function of the type of instructional cues, the amount of practice incorporated in cognitive pretraining, and the flight training history of the subjects. The experimental groups were found to be equivalent in terms of age, hours on the T-37 airplane, and hours on the T-4 simulator. The groups were not equivalent with respect to the number of hours of flying time logged prior to entering USAF training. The groups which received systematic cues had significantly more prior flight experience, $F\ (1,\ 28) = 12.17$, $p < .01$.

Adjustments were considered using an analysis of covariance procedure. Several reasons, however, led to the rejection of covariance analysis in favor of normal analysis of variance procedures.

1. Pearson product moment correlation coefficients were computed between three subject characteristics including hours of prior flying time and the scores on three composite perceptual-motor performance descriptors both for the straight and level warm-up period and for the Vertical S trials portion. None of the correlations reached $r = .6$, the preestablished criterion for covariance procedures.

2. The one significant correlation for error amplitude during the straight and level portion must be considered inconclusive since none of the other composite performance descriptors show correlations which come close to significance ($r \geq .268$). The correlations with the average trial performance scores are lower yet, and in this portion of the simulator performance, error amplitude does not correlate at all systematically with hours of prior flying time.

3. The perceptual-motor performance data showed heterogeneous group variances. Analysis of variance is relatively robust with respect to violations of the assumption of homogeneity of variance, whereas analysis of covariance procedures are far less robust against violations of this assumption (Elashoff, 1969).

4. Hours of prior flying time is a very incomplete indicator of pilot experience since it takes into account neither the type of flight training (private, commercial, military, single or multi-engine) nor the recency of such training. The potential effects of 50 hours of helicopter training two years before the experiment cannot be equated with 50 hours of military single engine light plane training one-half year before the experiment.

The reasons cited above were considered ample justification for the choice of normal analysis of variance procedures. In all analyses, the 2 X 2 design was analyzed first. Then, comparisons between the independent control group and the four experimental groups were performed where appropriate, using Dunnett's Test (Myers, 1966, p. 377).

Cognitive Performance

Cognitive mastery as measured by percent correct scores on the immediate posttest showed a significant instructional cues effect, F (1, 28) = 8.24, $p < .01$. Subjects who had received systematic cues achieved higher scores on the immediate posttest than those who had received current cues. Practice effects were not significant; neither were the interactions.

Measures of time through program and time through posttest showed significant effects for practice, but not for instructional cues. Subjects who had received a high amount of practice spent, of course, more time working through the program, F (1, 28) = 39.65, $p < .0001$; however, they spent significantly less time in completing the posttest, F (1, 28) = 39.65, $p < .05$. Interactions were not significant.

Program efficiency, measured as the quotient between percent correct on the posttest and time through program in minutes, showed a significant practice effect, F (1, 28) = 15.24, $p < .001$. Subjects in the low practice conditions made more correct responses on the posttest per minute of invested learning time than subjects in the high practice conditions. Group means for cognitive performance measures are shown in Table 1.

Perceptual Motor Performance

Three different types of derived scores, called performance descriptors, were computed from the raw data gathered on five cockpit instruments. This resulted in 15 single variable performance descriptors which could be summed across variables into the three composite performance descriptors time on criterion, hit rate, and error amplitude.

Analysis of variance procedures were applied to all 15 single variable scores as well as to the three composite performance scores. Separate analyses were conducted for the straight and level warm-up portion and for the six Vertical S trials. This amounts to a total of 32 separate analyses of variance. Since analyses on single variable scores permit evaluation of only one of five recorded variables of pilot performance at one time, primary consideration is given to reporting the results in terms of composite performance descriptors.

Straight and level warm-up. A significant cues effect favoring systematic cues (SC) was found for error amplitude, E_{Σ}, F (1,28) = 5.22, $p < .05$. No other comparisons between the experimental groups were significant. Dunnett's tests comparing each of the experimental groups with the independent control group did not reveal any significant differences.

Mean group scores on the three composite performance descriptors are shown in Table 2.

Groups	$\underline{n}$	Percent correct on posttest	Time through program[a]	Time through posttest[a]	Correct posttest per minute of time on text
Systematic cues					
Low practice	8	78.54	23.13	8.75	3.30
High practice	8	86.32	44.38	6.88	2.01
Current cues					
Low practice	8	61.84	24.63	8.50	2.76
High practice	8	62.43	40.50	6.75	1.76
No cues (control)	7	---	16.71	---	---

[a]in minutes

Table 1. Group Means for Cognitive Performance Measures

Groups	n	Performance descriptors		
		Error amplitude[a]	Hit rate[a]	Percent time on criterion[a]
Systematic cues				
Low practice	8	2.63	2.69	290.60
High practice	8	2.99	3.03	332.49
Current cues				
Low practice	8	5.66	2.62	282.93
High practice	8	3.86	2.85	307.76
No cues	7	3.79	2.96	310.01

[a]summed across variables

Table 2. Mean Group Scores for Perceptual-Motor Performance during Straight and Level Warm-up

Vertical S Trials. In order to obtain information about the effects of instructional cues and practice over the course of the six trials, trials was included in the analyses of this portion as a within-subjects factor.

Significant trials effects were found for error amplitude, F (5, 140) = 3.14, $p < .05$, for hit rate, F (5, 140) = 9.57, $p < .001$, and for percent time on criterion, F (5, 140) = 5.50, $p < .001$. A significant trials x instructional cues interaction was found for percent time on criterion, F (5, 140) = 2.49, $p < .05$.

The performance curves for the three levels of instructional cues are shown in Figures 1, 2, and 3 in percent time on criterion. All three performance descriptors yielded essentially the same shaped curves. Linear trend contrasts over six trials between systematic cues and current cues revealed significant differences between these two levels of instructional cues for error amplitude, F (1, 28) = 5.26, $p < .05$, and for percent time on criterion, F (1, 28) = 9.31, $p < .005$. Group performances within trials were evaluated by t tests. Significant differences were found for the two levels of instructional cues on each of the three composite performance descriptors (all < .05).

Dunnett's tests comparing each of the four experimental groups with the independent control group revealed no significant difference between mean performance scores over all six trials. When performance was compared by group and trial, eight out of a total of 72 contrasts were significant at $p < .05$. It was found specifically that the control group showed a significantly better performance on all three composite descriptors during Trial 1 than the groups which had received current cues (six contrasts). On Trial 6, the control group exhibited a significantly better performance on error amplitude and percent time on criterion than the group which had received systematic cues and a high level of practice (two contrasts). None of the correlations computed between cognitive posttest performance and perceptual-motor performance reached the .05 level of significant ($r \leq .268$).

Questionnaire

Analysis of the postexperimental questionnaire revealed no distinguishable differences between groups in the answers to Questions 1 through 6, 8, 9 and 11 through 14. (See Appendix)

The answers to Question 7 showed an effect for instructional cues, F (1, 28) = 7.29, $p < .05$. Groups which had received systematic cues reported less use of trim.

In Question 10, subjects were asked to rate the instructional treatments they had received during cognitive pretraining on four Likert-type scales (1 = low, 5 = hight). Subjects in the current cues/high practice condition rated the treatments significantly lower on every scale except on usefulness of drawings. The overall rating showed a significant practice effect, F (1, 28) = 5.20, $p < .05$, and a significant instructional cues x practice interaction effect,

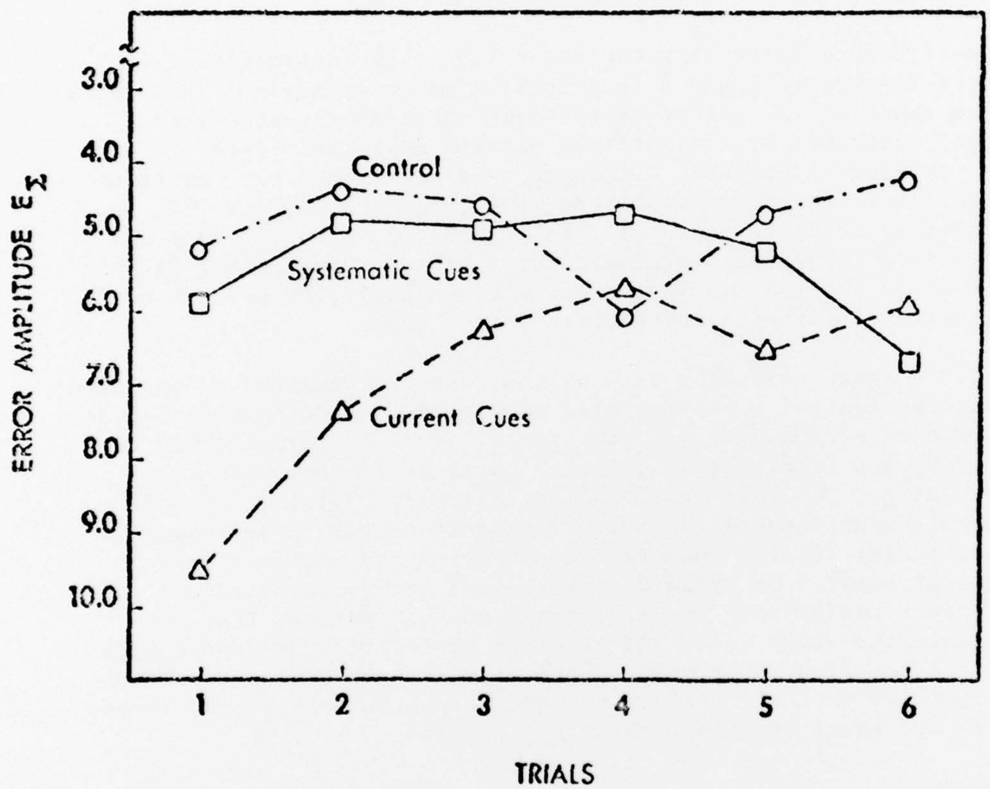

Figure 1. Perceptual-motor performance as measured by error amplitude (scores summed across variables) for three levels of cues over six trials (A x D interaction).

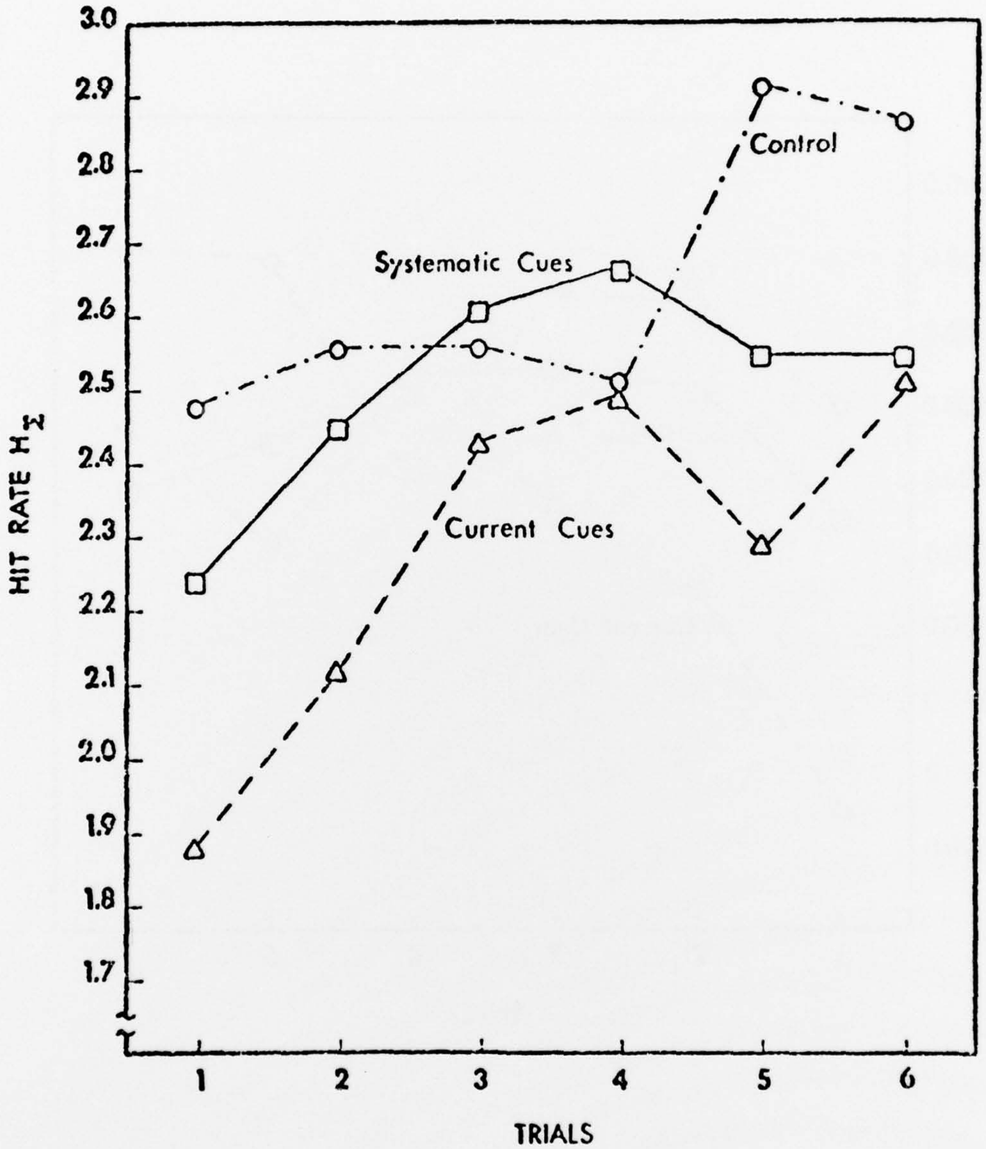

Figure 2. Perceptual-motor performance as measured by hit rate (scores summed across variables) for three levels of cues over six trials (A x D interaction).

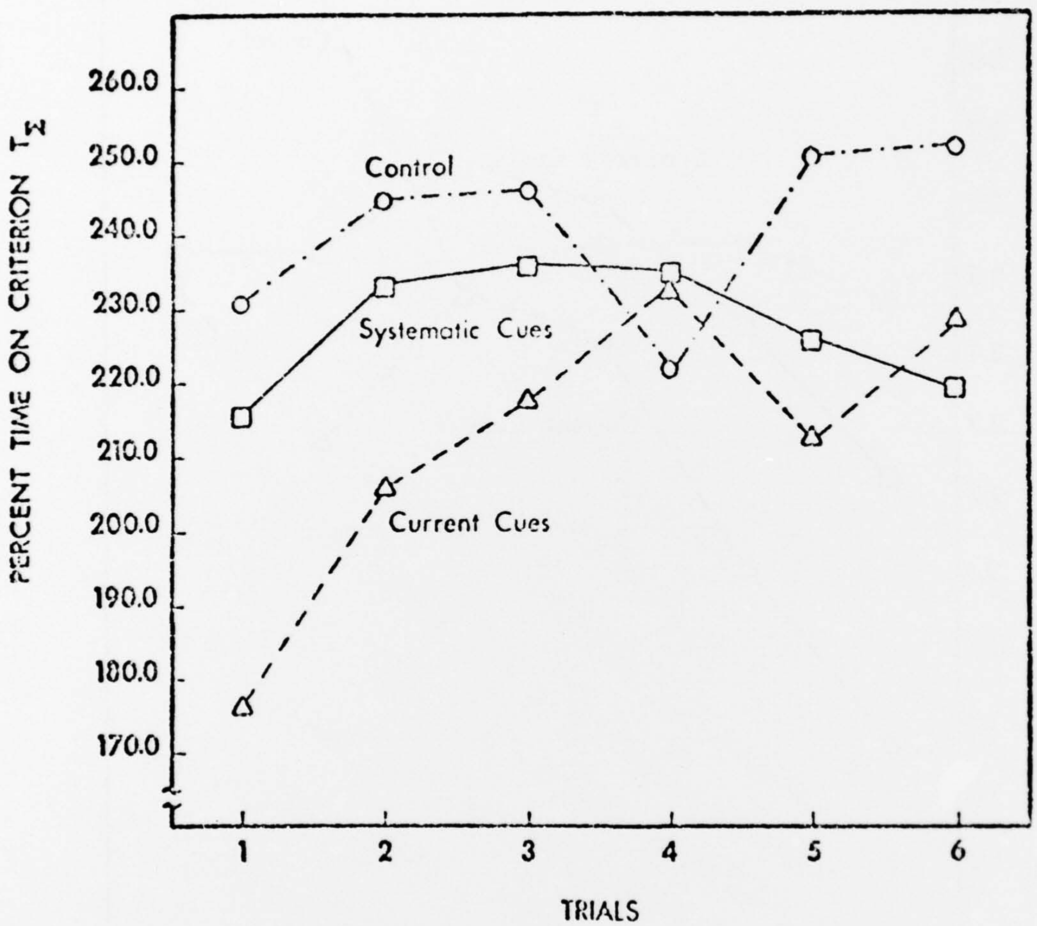

Figure 3. Perceptual-motor performance as measured by percent time on criterion (scores summed across variables) for three levels of cues over six trials (A x D interaction).

F (1, 28) = 7.26, $p < .05$, both of which are attributable to the low overall rating by the current cues/high practice group. The latter also differed significantly from the control group, *F* (1, 13) = 12.43, $p < .01$.

IV. Discussion

The primary goal of this study was the identification of variables which influence transfer from cognitive pretraining to perceptual-motor skill acquisition. The results clearly support the central hypothesis that the direction of transfer is dependent on the type of VPRs or instructional cues which were learned during cognitive pretraining. Systematically developed rules led to more precise perceptual motor behavior than currently operational rules, which appeared to inhibit rather than facilitate performance. The results did not confirm the hypothesis that the amount of cognitive practice would be directly related to the amount of transfer.

The most significant specific finding of the cognitive phase was the superior posttest performance of groups which had received systematic cues. Subjects in this treatment condition achieved posttest scores which were on the average 17 percent above those receiving current cues. These higher scores were achieved at no expense in terms of time through program. It follows that systematic cues were much more readily retained.

The amount of cognitive practice with a given set of cues did not influence posttest scores, but it did lead to differences in posttest time. Subjects in the high practice conditions had significantly shorter posttest times than subjects in the low practice conditions. Since the posttest consisted of a straightforward reproduction of a list of cues, this result shows clearly that the cues were more readily recalled by subjects in the high practice condition. It is important to note, however, that greater readiness of recall does not entail greater precision of recall. Readiness of recall or cognitive availability of cues appeared to be a function of practice, whereas precision of recall varied with the type of instructional cue.

The two levels of instructional cues which led to differences in the precision of cognitive performance led to similar differences in the precision of perceptual-motor performance. The relatively high and stable initial performance of the systematic cues groups contrasts with the much lower and gradually increasing initial performance of the current cues groups. By Trial 4, all experimental groups had merged at a performance level which represents a performance ceiling for all but the control group.

These differential performance patterns indicate that systematic cues facilitate perceptual-motor performance in a way which permits the learner to perform at or near ceiling performance from the beginning. Current cues, by comparison, initially inhibit performance. This inhibiting effect gradually disappears as indicated by the gradual convergence of the essentially flat performance curve (see Figure 1) for systematic cues and the steadily ascending curve for current cues. In the absence of a true zero point of transfer effects, statements about transfer can only be made in relative terms. When contrasted with current cues, systematic cues show positive transfer effects. Relative to systematic cues, current cues show negative transfer effects.

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The performance of the control group adds a reference point for these considerations on the effectiveness of VPRs. The control group subjects received the maneuver objective and were asked to write down the steps they would follow in executing the maneuver. This procedure essentially amounts to asking the subjects to analyze the maneuver and to supply their own cues. As Figure 1 shows, the control group performed at or above the performance level of the systematic cues groups. This result, which is in agreement with the superior performance for the "Analyzer" group in a study by Renshaw and Postle (1928), provides a positive boundary value of transfer with respect to the treatment conditions investigated so far. In relation to this boundary value, systematic cues can be considered maximally effective mediators of perceptual-motor skill, whereas current cues must be considered to be considerably less effective. The assumption that the direction of transfer is a function of the type of instructional cue is, therefore, supported at least in relative terms by the results of this study.

The two levels of cognitive practice which resulted in significantly different degress of cognitive availability of a given type of instructional cues did not lead to the predicted differences in perceptual-motor performance. Differences between systematic cues and current cues were expected to be smaller for low practice conditions than for high practice conditions. No significant performance differences due to practice effects were found.

It is speculated that the failure to find overall significant effects for the practice variable by regular analysis of variance procedures was at least to some extent a consequence of the instability of the T-4G simulator. In the questionnaire data, all but seven of the 39 subjects indicated that the simulator used in the experiment was "harder to fly" than either the aircraft or the regular training simulator. Increased information processing loads led to the common phenomenon of over-control, which in turn resulted in performance variances high enough to mask out any existing effects of the practice variable.

The high and heterogeneous variances associated with the perceptual motor data of the experimental groups also provide an explanation for the lack of significant correlations between cognitive mastery and perceptual-motor performance.

The second objective of the study was the discovery and validation of prescriptive principles for the design of perceptual-motor instruction. The predicted instructional effects of both previous research (Brecke et al., 1974) and the present study were confirmed by the experimental results which amount to an empirical validation of the design devices over two types of instructional treatments.

The results also provided empirical evidence for two previously uninvestigated considerations for the design of perceptual-motor instruction.

The high practice version of the instructional treatments was created by a straightforward repetition of identical mastery items. This manipulation led to a significant decrease of the instructional efficiency of the program and to negative attitudes on the part of the learners. The decrease of instructional efficiency was evidenced by the sharp increase of program time without concurrent increase in post-test scores. Evidence for the negative learner attitudes comes primarily from the significantly lower ratings for the instructional treatments which were given by the group which received current cues and high practice. It follows that instructional programs which are designed to provide cognitive pretraining should not incorporate repetitive practice of the type used in this study.

A second consideration for the design of perceptual-motor instruction stems from the performance exhibited by the control group. This group showed a very high performance for a very low investment in terms of cognitive pretraining time and an even lower investment in instructional development. The instructional treatment administered to the control group was definitely more efficient than all other instructional treatments administered. An instructional procedure which merely supplies the learner with an objective or with a precise idea of the desired goal performance and enlists the ingenuity of the learner in finding ways to attain this goal performance thus appears to be a more economical way to raise the instructional efficiency of pilot training than supplying the learner with explicit "how-to" rules which are very costly to develop. At the same time, such a procedure would be more effective than supplying the learner with instructional cues that are developed "on the spot" by instructor pilots who are not trained in instructional design.

If the learner is supplied with an explicit set of VPR's for each flight maneuver, he is essentially faced with the task of learning sets of procedures, i.e., lists of carefully sequenced sentences or sentence fragments. This may very easily lead to rote learning and mindless regurgitation. Even if rote learning can be avoided, this kind of instructional procedure is hardly conducive to the development of judgment, the ability to analyze flying tasks, and the ability to make autonomous decisions. It, therefore, appears that an instructional treatment which offers the possibility of attaining a high level of perceptual-motor performance on the one hand and a high level of generic cognitive skills on the other hand would be most advantageous.

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Appendix

Post Instruction Questionnaire

(The following questions are those to which reference is made in the text.)

6. Which part or aspect of the maneuver was the hardest?

____

____

8. What is the best pitch reference you can use during the maneuver?

____

9. If you had your choice, which instructional procedure would you prefer in order to prepare for flying?
(Number in order or preference)

    Selfstudy only
    Selfstudy plus briefing by IP
    Briefing by IP only
    Programmed Instruction
    Programmed Instruction plus briefing by IP

11. Which is harder to fly

    the simulator used in the experiment
    the regular simulator
    the aircraft?
    (check one)

14. Any other comments, remarks, suggestions?

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The primary goal of this study was the identification of variables which influence transfer from cognitive pretraining to perceptual-motor skill acquisition. The results clearly support the central hypothesis that the direction of transfer is dependent on the type of Verbral Prescriptive Rules (VPRs) or instructional cues which were learned during cognitive pretraining. Systematically developed rules led to more precise perceptual motor behavior than currently operational rules, which appear to inhibit rather than

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20. facilitate performance.

The second objective of the study was the discovery and validation of prescriptive principles for the design of perceptual-motor instruction. The predictive instructional effects of both previous research and the present study were confirmed by the experimential results which amount to an empirical validation of the design devices over two types of instructional treatments. The results also provided empirical evidence for two previously uninvestigated considerations for the design of perceptual-motor instruction. It appears that an instructional treatment which offers the possibility of attaining a high level of perceptual-motor performance on the one hand and a high level of generic cognitive skills on the other hand would be most advantageous.